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(54) **Automated laser fusion for high strength optical fiber splicing.**

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(73) Proprietor : Hughes Aircraft Company
7200 Hughes Terrace P.O. Box 45066
Los Angeles, California 90045-0066 (US)

(72) Inventor : Hsu, Hui-Pin
9360 Zeizah Avenue
Northridge, California 91325 (US)
Inventor : Jang, Soon
5055 Bakman Avenue, No. 305
N. Hollywood, California 91601 (US)
Inventor : Hinze, Lee R.
4493 Lubbock Drive
Simi Valley, California 93063 (US)

(74) Representative : Colgan, Stephen James et al
CARPMAELS & RANSFORD 43 Bloomsbury Square
London WC1A 2RA (GB)

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Description

The present invention relates to optical fiber technology. More specifically, the present invention relates to techniques for splicing optical fiber.

While the present invention is described herein with reference to illustrative embodiments for particular applications, it should be understood that the invention is not limited thereto. Those having ordinary skill in the art and access to the teachings provided herein will recognize additional modifications, applications, and embodiments within the scope thereof and additional fields in which the present invention would be of significant utility.

At present, only a few optical fiber manufacturers have the capability of making long, high strength, low loss, high quality fibers. Accordingly, optical fiber splicing is required more and more frequently to meet certain demanding applications.

High strength, low loss optical fiber splicing requires: 1) proper fiber preparation, 2) proper fiber alignment prior to fusion, 3) the bringing together and mating of the fibers during the fusion process, and 4) application of a precise temperature profile during the fusion and post fusion annealing processes.

Control of the temperature profile is of particular importance. The temperature profile is the timing of the application of specific amounts of thermal energy for controlled durations. Fiber splicing with inadequate control of the temperature profile may result in thermal shock, i.e., structural damage to the fiber.

Conventional fiber splicing techniques include hydrogen/oxygen flame torching, H-C1 gas flame splicing, and electric arc fusing. Hydrogen/oxygen flame torching was not an automated process. The temperature of the fiber had to be controlled by the operator. Splice quality was inconsistent due to the dependence on the skill of the operator. It was also difficult to align and control the movement of the fibers with the precision necessary to achieve a low loss splice. Hence, hydrogen/oxygen flame torching suffered low yields of high strength, low loss, high quality optical fiber due to poor control of the temperature profile, alignment and movement of the fiber.

H-C1 gas flame splicing was known to yield high strength splices, but H-C1 gas was found to be extremely hazardous.

Electric arc fusing is an automated process by which a computer controlled fiber positioner aligns the fiber ends face-to-face until optimum transmission is achieved through the junction. A high voltage is applied to two electrodes creating electric art induced heat. With an appropriate temperature profile, the temperature of the fiber reaches the melting point of glass, surface tension pulls the fiber ends together and the ends are fused. With insufficient heat, the glass will not melt. With excessive heat, the fiber ends melt away from each other.

While effective in providing a high strength splice, electric arc fusing has certain shortcomings. First, as with torch and flame splicing, it is somewhat difficult to control the temperature profile with this technique. Secondly, the ionized air gases generated by the electrode, tend to contaminate the fusion surfaces. As a result of the above problems this technique tends to yield inconsistent results.

Other prior art examples of optical fiber splicing apparatus and methods are disclosed in DE-A-3019425 and EP-A-0292146. Of these, DE-A-3019425 discloses an optical fiber splicing system comprising:

positioning means for moving end portions of at least two optical fibers until said end portions are in relative alignment at a splicing location;

a source providing a high intensity beam of energy;

means for directing the high intensity beam of energy along a beam path intersecting said splicing location; and

focus control means for controlling the focus of said beam and thereby controlling the temperature profile of the energy at said splicing location.

There is, however, still a need in the art for an optical fiber splicing system which affords better control of the splicing temperature without contamination. In addition, there is a need for a system which would apply fusion heat without disturbing the alignment of the fiber ends and without causing thermal shock to the fiber. Further, there is a need for a system which would provide consistent high strength, low optical loss fusion splicing.

The need in the art is addressed by the present invention which provides an improved optical fiber splicing system.

According to the present invention, there is provided an optical fiber splicing system comprising:

positioning means for moving end portions of at least two optical fibers until said end portions are in relative alignment at a splicing location;

a source providing a high intensity beam of energy;

means for directing the high intensity beam of energy along a beam path intersecting said splicing location; and

focus control means for controlling the focus of said beam and thereby controlling the temperature profile of the energy at said splicing location;

characterised by controller means including a microprocessor adapted to operate the focus control means to provide an optimum temperature profile throughout each of the various stages of the splicing operation.

The present invention further provides a method of splicing end portions of at least two optical fibers including the steps of:

a) positioning an end of each of at least two opt-

ical fibers in relative alignment at a splicing location;

b) directing a high intensity beam of energy at said splicing location; and

c) controlling the focus of said beam and thereby the temperature profile of the energy applied to said splicing location;

characterised in that the focus of said beam is controlled by controller means including a microprocessor to provide an optimum temperature profile throughout each of the various stages of the splicing operation.

Specific embodiments of the present invention are now described, by way of example only, with reference to the accompanying drawings, in which:-

Fig. 1 is an operational block diagram of the optical fiber splicing system of the present invention;

Fig. 2 is a simplified perspective diagram of the optical fiber splicing system of the present invention; and

Fig. 3 is a block diagram showing the electrical connections between the central components of the system of the present invention.

Fig. 1 is an operational block diagram of the optical fiber splicing system 11 of the present invention. The system 11 includes a fiber holder 13 which holds, for splicing, an end of a first coil of optical fiber 15. An xyz fiber positioner 17 is included for holding an end of a second coil of optical fiber 19. The fiber holder 13, xyz positioner 17 and associated controller 21 (not shown) are of conventional design and may be purchased from such manufacturers as the Klinger Scientific Company.

The end of the fibers 15 and 19 are moved into a coarse face-to-face coaxial longitudinal alignment at a junction 23 over a microscope objective 25 by the controller 21. An image is provided by the microscope 25 which is displayed on a television monitor 27 (not shown). A first 45 degree mirror 26 allows for a viewing, through the microscope 25, of the fiber ends at the junction 23 from a second angle.

The second fiber 19 is fed to the fiber positioner 17 through a local light injector source 29. The first fiber 15 is fed to the fiber holder 13 through a local light source sensor 31. The local light injection source and sensor are of conventional design and may be purchased from such manufacturers as the Ando Corporation of Japan. During the alignment of the fibers prior to splicing of same, the local light source injects an optical signal into the second fiber 19 which is transmitted thereby over the junction 23 into the first fiber 15. The optical signal strength in the first fiber 15 is detected by the local light injector sensor 31. The injector sensor 31 provides an electrical signal, indicative of the signal strength in the first fiber 15, to the xyz fiber positioning controller 21 via an interface controller 33 (not shown). A coarse alignment is provided by the xyz fiber positioner 17, controlled manually by the operator via the TV monitor and the local light injector readout, while a fine or precise alignment is accomplished by the preprogrammed controller 21 and the fiber positioning system including the injector source 29, sensor 31 and xyz positioner 17. That is, the suitably programmed controller 21 commands the fiber positioner 17 to bring the fibers together and to begin to align the fibers so that the lowest loss is obtained.

After the fibers are in precise alignment, in accordance with the present teachings, the fusing of the fibers 15 and 19 is accomplished by directing a high intensity beam of energy at the junction 23 of the fibers and controlling the focus of the beam to provide an optimum temperature profile of the energy applied to the splice. The beam 37 is provided by a laser 35. In the preferred embodiment, the laser 35 is a conventional 5 watt CW (continuous wave) CO_2 laser operating at the 10.2 micron wavelength necessary to heat the fibers.

The laser beam 37 is directed to the splicing junction 23 by second and third 45 degree mirrors 39 and 41 through a focus control assembly 43. As illustrated in the diagram of Fig. 2, the focus control assembly 43 includes a first movable lens 45, and second and third stationary lens 47 and 49. The position of the first lens 45 is controlled by the position controller 21 through a translation table and the selective activation of a D.C. motor 51. The motor 51 is shown as a block to illustrate that alternative lens actuation schemes may be used without departing from the scope of the present invention. For example, a coaxial type motor drive may be used to position the lens within the scope of the present teachings.

During the fusion process, the controller program commands the fiber positioner 17 to bring the fibers closer together. Heating continues and the temperature decreases as a result of the controller 21 moving the lens 45. After the completion of the fusion process, the operator simply removes the fibers from the holders.

Fig. 2 also illustrates the location of the microscope objective 25 relative to the fiber holder 13 and the fiber positioner 17. The longitudinal axis of the beam 37 is transverse to the longitudinal axes of the fibers 15 and 19. The laser beam 37 is dumped into a beam blocker 50 such as a fire brick.

Thus, as energy from the beam is applied to the fibers 15 and 19 at the junction 23, the lens 45 is moved to change the focus thereof to provide an optimum temperature profile for the fibers being spliced. One of ordinary skill in the art will be able to determine desired spot size and temperature profile used by the controller 21 to provide optimum control of the lens position during the splicing process.

The controller includes a microprocessor which executes a simple servo control program to provide control signals to the motor 51 effective to position

the lens 45 to provide the desired beam spot size and hence an optimum temperature profile. In the preferred embodiment, the control program was written in basic.

Fig. 3 is a block diagram showing the electrical connections between the central components of the system 11 of the present invention. Four channels of output are provided by the controller 21, three to control the three stepper motors which provide x, y, and z axis positioning of the fiber positioner 17, and one to control the axial movement of the first lens 47 of the focus control assembly 43.

The laser 35 is powered by a laser power supply 36 which is switched by the controller 21. The position controller 21 and the interface controller 33 receive power from a conventional power driver 38. Other power supplies and power connections have been omitted for the purpose of illustration. Those skilled in the art will be able to provide the necessary power connections for each of the components shown. Optimal alignment data from the local light sensor 31 is provided to the controller 21 through the interface controller 33 to signal the initiation of the fusion process.

Prior to splicing, the fibers should be prepared in a suitable conventional manner. The temperature profile should include a prefusing step during which the fibers are exposed to lower temperatures to burn off dust and other particles deposited on the surface of the fiber. Post fusion annealing and annealing steps should also be included within the profile to minimize thermal shock. In a post fusion annealing step, the beam spot size may be increased to four to five fiber diameters about the spliced junction. This allows a gradual cooling to reduce heat stress. During the annealing step, the spot size may be increased to 10 - 15 fiber diameters for further controlled cooling. The temperature profile depends on individual characteristic of the optical fiber.

The system 11 is enclosed within a cabinet 53 having hinged covers 55 and 57. An electrical interlock (not shown) disconnects power to the laser 35 and activates a mechanism (not shown) which moves the first mirror 26 into and out of operational position on the opening and closure of the covers 55 and 57.

Thus, the present invention has been described herein with reference to a particular embodiment for a particular application. Those having ordinary skill in the art and access to the present teachings will recognize additional modifications applications and embodiments within the scope thereof.

It is therefore intended by the appended claims to cover any and all such applications, modifications and embodiments within the scope of the present invention.

Claims

1. An optical fiber splicing system (11) comprising:

    positioning means (17) for moving end portions of at least two optical fibers (15, 19) until said end portions are in relative alignment at a splicing location (23);

    a source (35) providing a high intensity beam (37) of energy;

    means (39, 41) for directing the high intensity beam (37) of energy along a beam path intersecting said splicing location (23); and

    focus control means (43) for controlling the focus of said beam (37) and thereby controlling the temperature profile of the energy at said splicing location (23);

    characterised by controller means (21) including a microprocessor adapted to operate the focus control means (43) to provide an optimum temperature profile throughout each of the various stages of the splicing operation.

2. A system according to claim 1, wherein said focus control means (43) includes a first lens (45) in the path of said beam (37).

3. A system according to claim 2, wherein said focus control means (43) includes motor means (51) operatively connected to said first lens (45) for selectively moving said first lens (45) along said beam path toward and away from said splicing location (23).

4. A system according to claim 3, wherein said focus control means (43) includes second and third lenses (47, 49) in optical alignment with said first lens (45).

5. A system according to any preceding claim, wherein said positioning means (17) includes light source means (29) for injecting optical energy through a first one of said optical fibers (15, 19) and into a second one of said optical fibers (15, 19) through said relatively aligned end portions.

6. A system according to claim 5, wherein said positioning means (17) includes means (31) for sensing the optical energy in said second one of said optical fibers (15,19).

7. A system according to any preceding claim, wherein said positioning means (17) includes a monitor (27) for providing an indication of the relative position of said optical fibers (15, 19).

8. A method of splicing end portions of at least two optical fibers (15, 19) including the steps of:

a) positioning an end of each of at least two optical fibers (15, 19) in relative alignment at a splicing location (23);
b) directing a high intensity beam (37) of energy at said splicing location (23); and
c) controlling the focus of said beam (37) and thereby the temperature profile of the energy applied to said splicing location (23);

characterised in that the focus of said beam (37) is controlled by controller means (21) including a microprocessor to provide an optimum temperature profile throughout each of the various stages of the splicing operation.

Patentansprüche

1. Ein Spleißsystem (11) für optische Fasern mit: einer Positioniervorrichtung (17) zum Bewegen von Endteilen von wenigstens zwei optischen Fasern (15, 19) soweit, bis die Endteile bei einem Spleißort (23) sich in einer relativen Ausrichtung zueinander befinden;
einer Quelle (35) zur Bereitstellung eines Energiestrahles (37) mit hoher Intensität;
einer Vorrichtung (39, 41) zum Führen des Energiestrahles (37) mit hoher Intensität entlang eines Strahlpfades, der den Spleißort (23) schneidet; und
einer Fokus-Regelvorrichtung (43) zum Einstellen des Fokusses des Strahles (37) und dadurch zum Einstellen des Temperaturprofils der Energie bei dem Spleißort (23), gekennzeichnet durch eine Regeleinrichtung (21), die einen Mikroprozessor enthält, der ausgelegt ist, die Fokus-Regelvorrichtung (43) derart zu betreiben, daß sie für ein optimales Temperaturprofil über eine jede der verschiedenen Stufen des Spleißvorganges hinweg sorgt.

2. Ein System nach Anspruch 1, worin die Fokus-Regelvorrichtung (43) in dem Pfad des Strahles (37) eine erste Linse (45) enthält.

3. Ein System nach Anspruch 2, worin die Fokus-Regelvorrichtung (43) eine Motorvorrichtung (51) enthält, die operativ mit der ersten Linse (45) verbunden ist, um die erste Linse (45) selektiv entlang des Strahlpfades zu bewegen, und zwar hin und weg von dem Spleißort (23).

4. Ein System nach Anspruch 3, worin die Fokus-Regelvorrichtung (43) zweite und dritte Linsen (47, 49) in optischer Ausrichtung mit der ersten Linse (45) enthält.

5. Ein System nach einem der vorigen Ansprüche, worin die Positioniervorrichtung (17) eine Lichtquellenvorrichtung (29) enthält, zum Injizieren von optischer Energie durch eine erste der optischen Fasern (15, 19) hindurch und in eine zweite der optischen Fasern (15, 19) hinein, und zwar über die relativ zueinander ausgerichteten Endteile.

6. Ein System nach Anspruch 5, worin die Positioniervorrichtung (17) eine Vorrichtung (31) enthält, um die optische Energie in der zweiten der optischen Fasern (15, 19) zu detektieren.

7. Ein System nach einem der vorigen Ansprüche, worin die Positioniervorrichtung (17) einen Monitor (27) enthält, um eine Anzeige der relativen Position der optischen Fasern (15, 19) bereitzustellen.

8. Ein Verfahren zum Verspleißen von Endteilen von wenigstens zwei optischen Fasern (15, 19), welches die Schritte umfaßt:
a) Positionieren eines Endes einer jeden der wenigstens zwei optischen Fasern (15, 19) in relativer Ausrichtung zueinander bei einem Spleißort (23);
b) Führen eines Energiestrahles (37) mit hoher Intensität zu dem Spleißort (23); und
c) Einstellen des Fokusses des Strahles (37) und damit des Temperaturprofiles der Energie, die bei dem Spleißort (23) aufgewendet wird, dadurch gekennzeichnet, daß
d) der Fokus des Strahles (37) von einer Steuereinrichtung (21) geregelt wird, die einen Mikroprozessor enthält, um für ein optimales Temperaturprofil über einen jeden der verschiedenen Stufen des Spleißvorganges hinweg zu sorgen.

Revendications

1. Système (11) d'épissage de fibres optiques comportant :
des moyens (17) de positionnement destinés à déplacer des parties extrêmes d'au moins deux fibres optiques (15, 19) jusqu'à ce que lesdites parties extrêmes soient en alignement relatif en un emplacement (23) d'épissage ;
une source (35) produisant un faisceau d'énergie (37) à haute intensité ;
des moyens (39, 41) destinés à diriger le faisceau d'énergie (37) à haute intensité le long d'un trajet de faisceau coupant ledit emplacement (23) d'épissage ; et
des moyens (43) de commande de focalisation destinés à commander la focalisation dudit faisceau (37) et à commander ainsi le profil de température de l'énergie audit emplacement (23)

d'épissage ;

caractérisé par des moyens (21) de commande comprenant un microprocesseur conçu pour faire fonctionner lesdits moyens (43) de commande de focalisation afin de produire un profil de température optimal pendant la totalité de chacun des divers stades de l'opération d'épissage.

2. Système selon la revendication 1, dans lequel lesdits moyens (43) de commande de focalisation comprennent une première lentille (45) sur le trajet dudit faisceau (37).

3. Système selon la revendication 2, dans lequel lesdits moyens (43) de commande de focalisation comprennent un moyen à moteur (51) relié fonctionnellement à ladite première lentille (45) pour déplacer sélectivement ladite première lentille (45) le long dudit trajet du faisceau afin de la rapprocher et l'éloigner dudit emplacement (23) d'épissage.

4. Système selon la revendication 3, dans lequel lesdits moyens (43) de commande de focalisation comprennent des deuxième et troisième lentilles (47, 49) en alignement optique avec ladite première lentille (45).

5. Système selon l'une quelconque des revendications précédentes, dans lequel lesdits moyens (17) de positionnement comprennent un moyen (29) à source de lumière destiné à injecter de l'énergie optique dans une première desdites fibres optiques (15, 19) et dans une seconde desdites fibres optiques (15, 19) à travers lesdites parties extrêmes relativement alignées.

6. Système selon la revendication 5, dans lequel lesdits moyens (17) de positionnement comprennent un moyen (31) destiné à capter l'énergie optique dans ladite seconde desdites fibres optiques (15, 19).

7. Système selon l'une quelconque des revendications précédentes, dans lequel lesdits moyens (17) de positionnement comprennent un moniteur (27) destiné à fournir une indication de la position relative desdites fibres optiques (15, 19).

8. Procédé d'épissage de parties extrêmes d'au moins deux fibres optiques (15, 19), comprenant les étapes qui consistent :

a) à positionner une extrémité de chacune d'au moins deux fibres optiques (15, 19) en alignement relatif en un emplacement d'épissage (23) ;

b) à diriger un faisceau d'énergie (37) de haute intensité sur ledit emplacement d'épissage (23) ; et

c) à commander la focalisation dudit faisceau (37) et ainsi du profil de température de l'énergie appliquée audit emplacement d'épissage (23) ;

caractérisé en ce que la focalisation dudit faisceau (37) est commandée par des moyens (21) de commande comprenant un microprocesseur pour établir un profil de température optimal durant la totalité de chacun des divers stades de l'opération d'épissage.

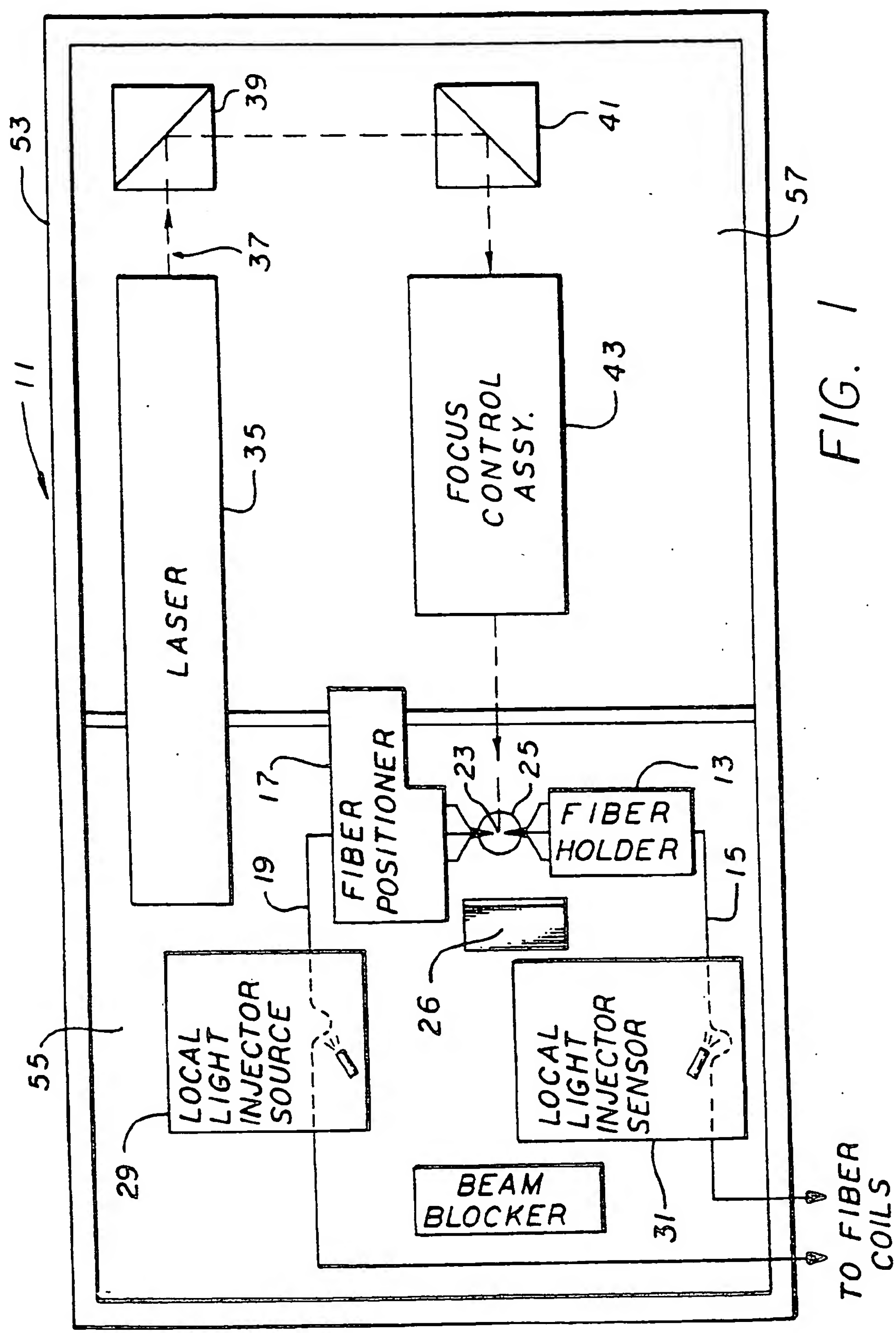

11
53
39
41
57
37
LASER
35
FOCUS CONTROL ASSY.
43
17
FIBER POSITIONER
23
25
FIBER HOLDER
13
19
15
26
55
LOCAL LIGHT INJECTOR SOURCE
LOCAL LIGHT INJECTOR SENSOR
29
31
BEAM BLOCKER
TO FIBER COILS

FIG. 1

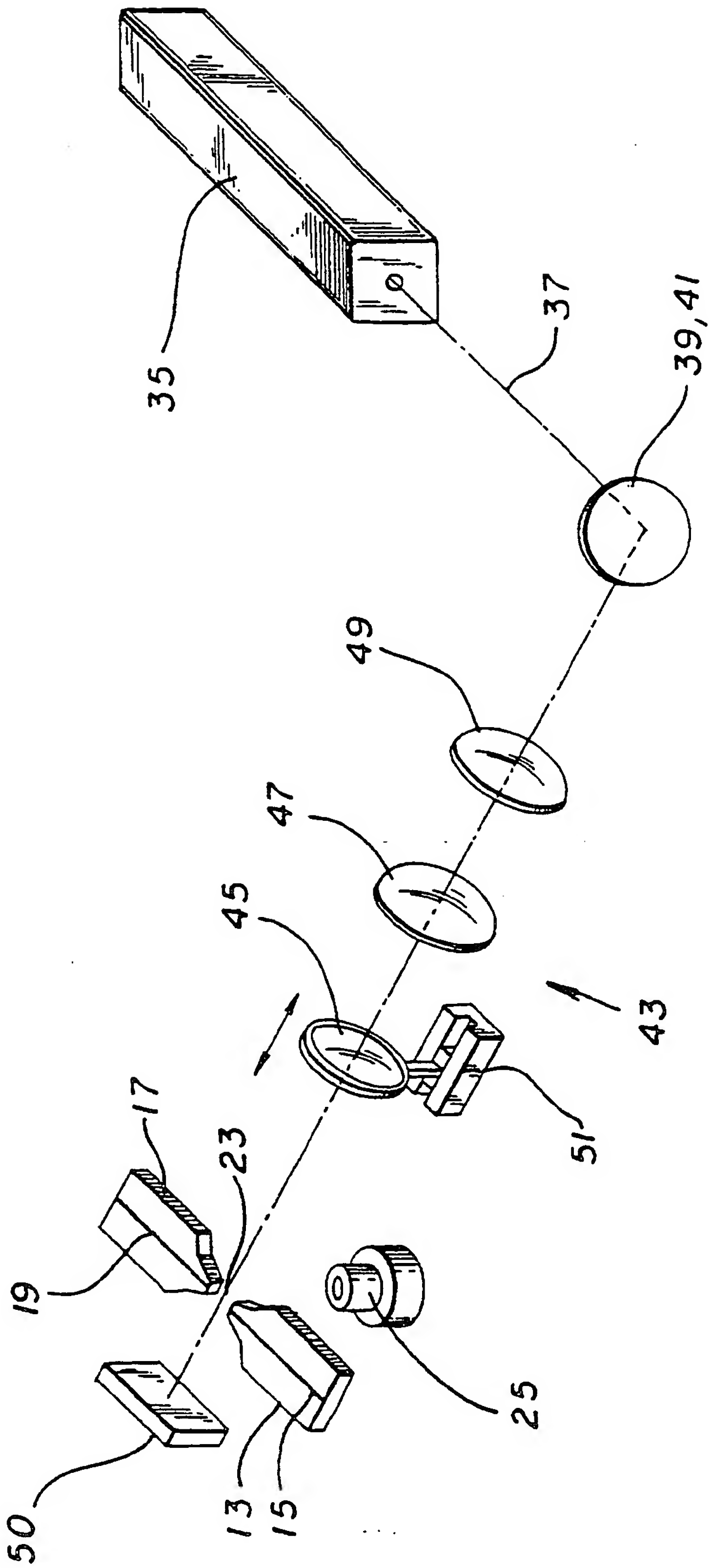
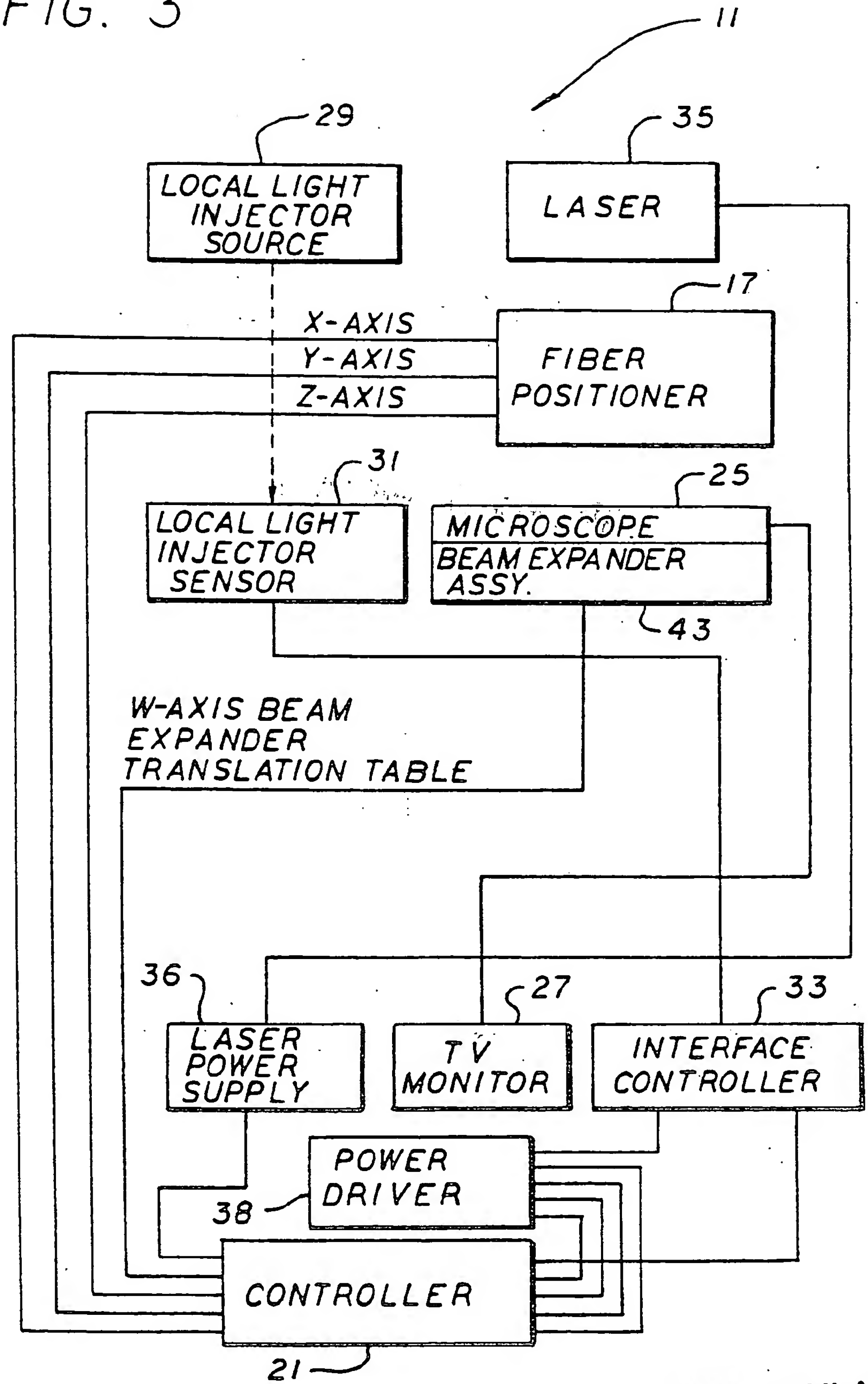


FIG. 2

FIG. 3


11
29
LOCAL LIGHT INJECTOR SOURCE
35
LASER
17
X-AXIS
Y-AXIS
Z-AXIS
FIBER POSITIONER
31
LOCAL LIGHT INJECTOR SENSOR
25
MICROSCOPE
BEAM EXPANDER ASSY.
43
W-AXIS BEAM EXPANDER TRANSLATION TABLE
36
LASER POWER SUPPLY
27
TV MONITOR
33
INTERFACE CONTROLLER
POWER DRIVER
38
CONTROLLER
21